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Form 10

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FOR OFFICE USE

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Complete Specification for the invention entitled: APPLICATION OF DIFFERENTIAL OR POWER SHUNT TYPE TORQUE CONVERTERS TO DUAL MODE TRANSPORTATION AND THE LIKE.

The following statement is a full description of this invention, including the best method of performing it known to me:—*

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*Note: The description is to be typed in double spacing, pica type face, in an area not exceeding 250 mm in depth and 160 mm in width, on tough white paper of good quality and it is to be inserted inside this form.

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F. D. Atkinson, Government Printer, Canberra

O.T. 1-9-77.

This invention relates to a method of providing mechanical energy in dual mode applications; that is where in one mode, (which we shall refer to as the electric mode), electrical energy is converted into mechanical energy, and in a second mode (the non-electric mode), an output of mechanical energy is required for an input of mechanical energy.

This invention, which we shall refer to as a dual mode energy transmission and conversion system, was conceived in relation to dual mode transportation, where vehicles are designed to run on conventional roads in one mode, and to draw the energy for propulsion from an electric conductor rail, when operating on electric roads. Other applications are possible, but it is best explained in relation to such dual mode transport systems.

A dual mode vehicle must have means for storing energy for operating on conventional roads. Perhaps the simplest solution is to store electrical energy in a storage battery, and to use the same electric motor, or motors in both modes. But the inadequacy of present batteries is, itself, a compelling force urging the electric road upon us. Until the transition from conventional to electric roads has advanced to the stage where travel on the remaining conventional roads is so small that storage batteries, even in their present form, would be adequate, we must look to the existing solutions to self contained automobility—heat engines, which in most cases require a torque converter to couple them to the wheels.

In one solution to this dual mode problem, a heat engine with its own torque converter is coupled to the wheels in the non electric, with an electric motor used only in the electric mode. A second solution makes use of the electric motor, or motors, in a purely electrical system of torque conversion (like that used on diesel-electric railway locomotives), to drive the wheels in both modes. But we may still have an uneasy conscience about the idle generator, uselessly coupled to the prime mover, when operating on an electric road.

Fig.I shows a generator, G, coupled to the mechanical input, IP, by means of a clutch, CI, for uncoupling the generator from the prime mover and coupling it to the motor, M, by means of C2. In the electric mode G could be used as a motor, and the maximum power available would be roughly double that in conventional operation. This may be an ideal characteristic where speeds are much higher on the electric road than off it.

The opposite extreme is illustrated in Figs.22,23,24 and 25, being longitudinal cross sections along the axes of the machines. The inputs and outputs are shown as IP and OP respectively, GR is one element of an electrical machine, GS is the other, concentric element which interacts with it, but the cylindrical form suggested by these diagrams, and most of the others, is of course not the only form possible, even where discussion is limited to rotating machines. GS and GR, and MS

and MR introduced later, are meant to refer to the elements of electrical machines of the most general possible type.

In Figs.22,23,24 and 25, the input mechanical torque is transferred, by electrically generated forces acting between GS and GR, to the output OP. Such a torque converter will be inefficient where GR and GS have a large relative slip. If such a device were designed on the basis that periods of high slip would be short lived, and that normally little energy would be converted into electrical energy, then in the electric mode we would have an electrical machine of much lower rating than the prime mover.

Between Fig.I in which no energy is transmitted mechanically and Figs.22 to 25, in which no energy is transmitted electrically there lies a class of torque converters, in which part of the energy is transmitted mechanically and part electrically. Examples of such differential, or power shunt type electric torque converters are shown in Figs.2,3,4,5,6,7,8,I2,I4,I5,I6, I7,I8,I9, and 20.

In all the above examples, with the exception of Fig.I7, when the speed of OP is small, a large proportion of the input mechanical energy is converted into electrical energy, and a large additional torque or force can be produced in the motor section, by the interaction of the elements MR and MS. When the speed of OP and IP is such that the relative speed of the generator elements is small, little energy need be converted, and the motor could even be disconnected, the

generator merely supplying its own losses. Thus it can be seen that Figs.22,23,24 and 25, represent degenerate cases of the power shunt torque converter, and can be obtained by a change in electrical connections.

Similarly by, for example, by interposing a clutch between GS and MR, and locking GS, in Fig.4 the power shunt torque converter degenerates to the all electric system.

Now suppose IP were fixed relative to the frame F, by means of some kind of locking mechanism, represented diagrammatically by B, in Figs.2,3,4,5,6,7,8,12,14,15,16,17,18,19, and 20. The generator section could the be used as a motor, and the maximum power available in the electric mode wouldlie between the two extreme cases above. But B need not be operative all the time the system is in the electric mode; any system, as described, employing such a mechanism falls within the scope of the present invention. Similarly, the generator section in such two electrical machine systems, could be arranged as a motor, to feed mechanical energy out through IP, to "charge" a flywheel or the like, or to start a prime mover, such as a petrol engine, which needs to be cranked to start.

Within that class of embodiments which employ one, two, or even three principal electrical machines, it is possible to subdivide into those which employ a differential gear train of some type, or its equivalent where other than rotary motion is used, and those which do not. Fig.12 and 13 show two possible types of gear trains, where in Fig.13, S is the

sun gear, P a planet, PC a planet carrier and R the ring gear. Fig.I9 shows yet another type of differential gear train. Figs.IO and II show a linear equivalent where the links, LI, L2, and L3 execute a reciprocating motion. Numerous embodiments are made possible according to which element of the different-ial gear train is connected to what. Figs.I6,23,24, and 25, show a general differential gear train DG, with various internal permutations being possible, two of which for Fig.I6 are shown in Figs.I4 and I5. One virtue of the systems employing differential gear trains and the like, is that GS and MS can be truely stationary, relative to the frame, altho-ugh this is not necessary.

We are not limited to rotary motion and any suitable form of motion may be used. A system, which in the non electric mode, converts oscillating motion into contuous rotary motion, is shown in Figs.6 and 7, Fig being an end view, and Fig.7 a longitudinal cross section. GRI and GR2 oscillate I80° out of phase, but this is not essential and is merely the result of coupling the links RI, LI, R2 and L2 with a reciprocating member, which may be looked by B, for pure rotary operation in the electric mode. GRI contributes torque only when moving in one direction, and is idle on the return stroke. GR2 is providing a torque then bowever, the whole action is like a rachet with alternately operating pawls. As before the energy which is converted into electrical energy may be transmitted to the motor section, MR and MS.

Fig.8 illustrates a reciprocating version with both input and output members reciprocating. This is clearly the linear analogue of Fig.2. Fig.9 is a set of graphs of input and output speed and force plotted against time, for such a mechanism as Fig.8. By means of automatic switching devices, not shown, GS imparts a force to GR and so to OP, only when the input speed has the same direction as the output speed. This force is added to the force produced by the interaction of MR and MS to produce an output force vs. time curve of the form shown in the final graph.

The embodiments shown in Figs.2,3,4,5,6,7,8,12,14,15 and 16 are all torque, or force increasers and speed reducers in the non electric mode. By swapping the functions of generator and motor this can be reversed to torque or force reducers and speed increasers. (Strictly speaking this ignores the effect of gear trains interposed between input and output.)

A second class of machines could be produced by simply turning the above diagrams through 180° and swapping IP and OP. Fig.17 is in fact Fig.2 transformed in this way. Where the the element thus connected to the input remains part of a motor a torque, or force increase and speed reduction are obtained. The functions of motor and generator can similarly be reversed in this class of embodiments to give the reverse effect.

So far we have limited discussion to at most two electrical machines. Three are possible, without duplication, as shown in

Figs.I8 and I9, even where we restrict ourselves to one input and one output. In Fig.I8, it would be possible to use all three machines as motors without physically coupling GRI and MR but this may be done if desired by means of a mechanism such as C2, which couples GS2 to MR in the non electric mode, where straight through drive is not required, and GR2 to MR in the electric mode. GS2 would then have to be locked by a brake B',or the like. Fig.I9 shows a similiar system, which has the virtue, not drawn in any of the other differential systems, although possible there too, that the gears are not in relative motion, when operating in the electric mode.

There are a large number of permutation possible, amongst the types considered so far, but where the number of mechanical inputs and/or outputs is increased beyond one, as in Figs.20 and 2I, the possibilities are enormous.

The diagrams are by no means exhaustive. Many embodiments falling within the scope of the present invention are feasible, and it would be impossible to describe them all. in the space available

The claims defining the invention are as follows:—

(I). A dual mode energy transmission and conversion system, comprising in the most general case, inputs and outputs for mechanical energy, and inputs and outputs for electrical energy, so that in one of its principal modes of operation, which shall be referred to as the electric mode, electrical energy is supplied to the system and is substantially converted into mechanical energy, which mechanical energy is obtained at an output, or outputs, or flows in a reverse sense through what it will be convenient to call an input, or inputs, into means for storing mechanical energy, or both simultaneously depending on the particular embodiment and the circumstances; and in a second mode, which shall be referred to as the non electric mode, mechanical energy is applied to an input, or inputs, and an output, or outputs of mechanical energy obtained, this latter process being characterised by the conversion of some part of the input mechanical energy into electrical energy, for at least some conditions of operation in this mode; said conversion taking place in an electrical machine, or machines, and said machine, in enbodiments which have only one, is used to convert electrical energy into mechanical energy, and in embodiments where two or more such machines are used, all of said machines, or any combination, fixed in some embodiments but with provision to change from one combination to another, to suit circumstances, in other embodiments) are used to convert an input of electrical

energy into mechanical energy.

(2). A dual mode energy transmission and conversion system, comprising an input and an output for mechanical energy, and an input for electrical energy, and in which in the non electric mode, mechanical energy is transmitted from mechanical input to output, via two paths, one mechanical, the other electrical. Part of the input mechanical energy is converted into electrical energy (in an electrical machine, or machines which will hereafter be referred to as a generator, or generators), and substatially the whole of said electrical energy is transmitted and reconverted into mechanical energy, (in an electrical machine, or machines, which will hereafter be referred to as a motor, or motors) and combined with the remainder which was transmitted mechanically. The proportion of the input mechanical energy which is transmitted electrically is fixed in some embodiments, and variable in others, and may take extreme values approaching unity in some embodiments, in which case no energy is transmitted via the mechanical p path, or of zero in other embodiments, in which case no energy is transmitted via the electrical path, and in further embodiments said proportion may be variable and assume one or other of these extreme values under some operating conditions. At least some if not all, of the electrical energy which is in the case where no energy is transmitted electrically is consummed in losses, within the generator, or generators. The combination of all of the above embodiments with the feature

that said generator, or generators, is or are, transformed by suitable means, so as to convert an input of electrical energy into mechanical energy when operating in the electric mode constitutes Claim 2.

(3). A dual mode energy transmission and conversion system, comprising a frame, an input member, an output member, two generator elements, and in addition in a large number of embodiments two motor elements, said input member, output member, and some or all of the other elements, described above according to the particular embodiment of the system, either rotating, reciprocating, oscillating or executing any other suitable form of motion relative to the frame. In one class of embodiments of the system, one generator element is coupled to the input member and the other generator element is coupled to the output member; a torque or force applied to the input member is substantially transmitted to the output member by means of electrically generated forces acting between the two generator elements. In a second class of embodiments the electrical energy produced in the generator is substantially converted into mechanical energy by the interaction of the motor elements, and the torque, or force so produced added to the torque, or force transmitted through the generator. In a third class of embodiments one generator element is fixed to the frame, the other coupled to the input member, and to a motor element, and a torque, or force, applied to the input member is opposed by the interaction of the generator elements

so that a reduced torque, or force is transmitted to the motor element which is coupled to the input member via a generator element. The electrical energy produced in the generator is substantially converted into mechanical energy in the motor, so that an angular or translational velocity is to the velocity possessed by the motor element which is coupled to the input member. In a fourth class of embodiments substatially the whole of the input mechanical energy is converted into electrical energy in a generator, and said energy is substantially converted into mechanical energy in a motor. The combination of all the embodiments within these four classes, with the feature that said generator is transformed, by suitable means, to function as an electric motor, so that an input of mechanical energy is converted into mechanical energy when operating in the electric mode constitutes Claim 3.

(4). A dual mode energy transmission and conversion system, comprising a frame, elements and members as claimed in Claim 3, with the addition of a differential, planetary, or similiar gear train, or the analogues of such gear trains where other than rotary motion is used, such mechanisms being characterised by having three variables which define their state, such as for example the angular positions of the shafts in a gear train, and furthermore the value of one of said three variables is completely determined by the values of the other two. The The shafts, or other moving members of such mechanisms, the

frame, the input member, the output member, the generator elements, and where used the motor elements, may be coupled together to form numerous embodiments of the system. The combination of all of said embodiments with the feature that said generator is transformed by suitable means, to function as an electric motor so that an input of electrical energy is converted into mechanical energy when operating in the electric mode, constitutes claim 4

(5). A dual mode energy transmission and conversion system, comprising two electrical machines, as for some embodiments claimed in claims 3 and 4, one of which electrical machine acts as a generator, the other as a motor, when operating in the non electric mode, (although these roles may be interchanged whilst operating in the non electric mode), in combination with the feature that, when operating in the electric mode, said two electrical machines may be used in one of the following three ways to provide mechanical power, firstly they may both be used as motors, secondly the machine which serves as the generator in the non electric mode, may be used by itself, and thirdly, the motor may be used by itself, in these latter two conditions, as a motor, and in some embodiments changes can be made from one condition to another to suit varying operating requirements.

(6). A dual mode energy transmission and conversion system, as claimed in claims 3 and 4 with the addition of a third electrical machine, whose two elements are coupled to other

elements, input and output members, members of a differential mechanism, where used, and the frame in such a way that the physical connections of another electrical machine are not merely duplicated, so as to form numerous embodiments of the system. The combination of all said embodiments with the feature that all three electrical machines, or any combination of two, or any of the three acting by itself, may be used to convert an input of electrical energy into mechanical energy, and that in some embodiments changes can be made from on condition to another, when operating in the electric mode constitutes claim 6

(7). A dual mode energy transmission and conversion system, as claimed in claims 2, 3, 4 and 6 with the addition of extra inputs and/or outputs for mechanical energy, and electrical machines and differential gears as required, with the feature that all the electrical machines may be used together, or in various combinations, in a similiar way to that claimed in claims 5 and 6.

(8). A dual mode energy transmission and conversion system, as claimed in claims 2, 3, 4, 6, and 7 with a means for storing mechanical energy coupled to the input, or inputs, for mechanical energy, so that an input of electrical energy may be convertedinto mechanical energy, said mechanical energy flowing out thoough the input , or inputs and stored, or a proportion flowing in this sense, the remainder flowing through the outputs, or outputs, or the whole of said energy

mechanical energy flowing through the output as previously claimed. When operating in the non electric mode, energy is withdrawn from the means for storing mechanical energy, and applied to an input, or inputs, (where for our purposes it becomes indistinguishable from mechanical energy produced in any other way) and transmitted to the output, or outputs as claimed previously.

(9). A dual mode energy transmission and conversion system, as claimed previously, with the addition of means for storing electrical energy, so that when operating in the non electric mode electrical energy may be withdrawn from said means, and converted into mechanical energy within the system where the input mechanical energy is less than the required output mechanical energy, or conversely where there is an excess of mechanical energy this may be converted in the system and stored, and similarly when oprating in the electric mode, said means of storing electrical energy may either store, or supplement the input electrical energy.

(IO).A dual mode energy transmission and conversion system, as claimed previously, with provision for converting a flow of mechanical energy, in a reverse sense from an output, or outputs, into the system; into electrical energy which may be stored, as claimed in claim 9, or fed in a reverse sense out through the electrical energy input; or said mechanical energy may be transmitted in part mechanically, and in part electrically, and stored in a means of storing mechanical

energy as claimed in claim 8.

(II). A dual mode vehicle, comprising a dual mode energy transmission and conversion system as claimed, a prime mover or prime movers, or a means for storing mechanical energy as claimed in claim 8, or a combination of both, and means for collecting electrical energy from a source, or sources external to the vehicle.

(I2). A dual mode vehicle as claimed in claim II, with means for storing electrical energy, as claimed in claim 9 or on a smaller scale a means for storing electrical energy, whose chief function would be to provide starting current for prime movers, either using separate electrical machines for starting purposes, or a suitable machine within the dual mode energy transmission and conversion system, and with-drawing sufficient energy from the system, to keep the means "charged".

The claims defining the invention are as follows: *

Dated this 20 day of July, 1973

STEPHEN JOHN ELLIOTT

NAME OF APPLICANT
(BLOCK LETTERS)

*Note: If there is insufficient space above to type the statement of claim, do not use this sheet, but use separate sheet of paper beginning with the words "The claims defining the invention are as follows:" and ending with the date and the name of the applicant in block letters.

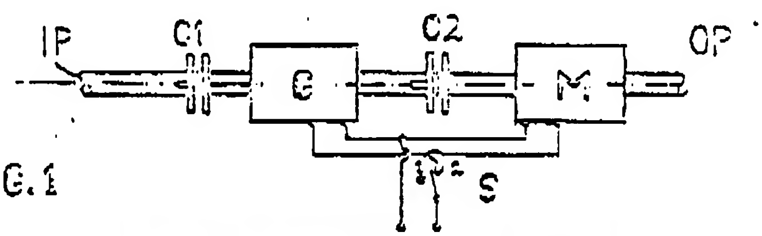

FIG. 1

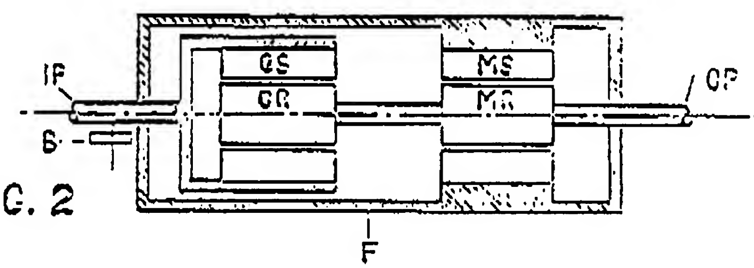

FIG. 2

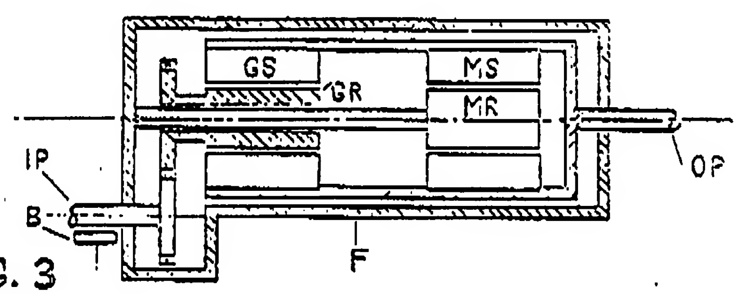

FIG. 3

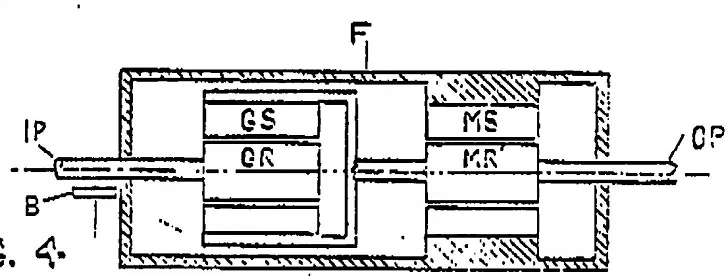

FIG. 4

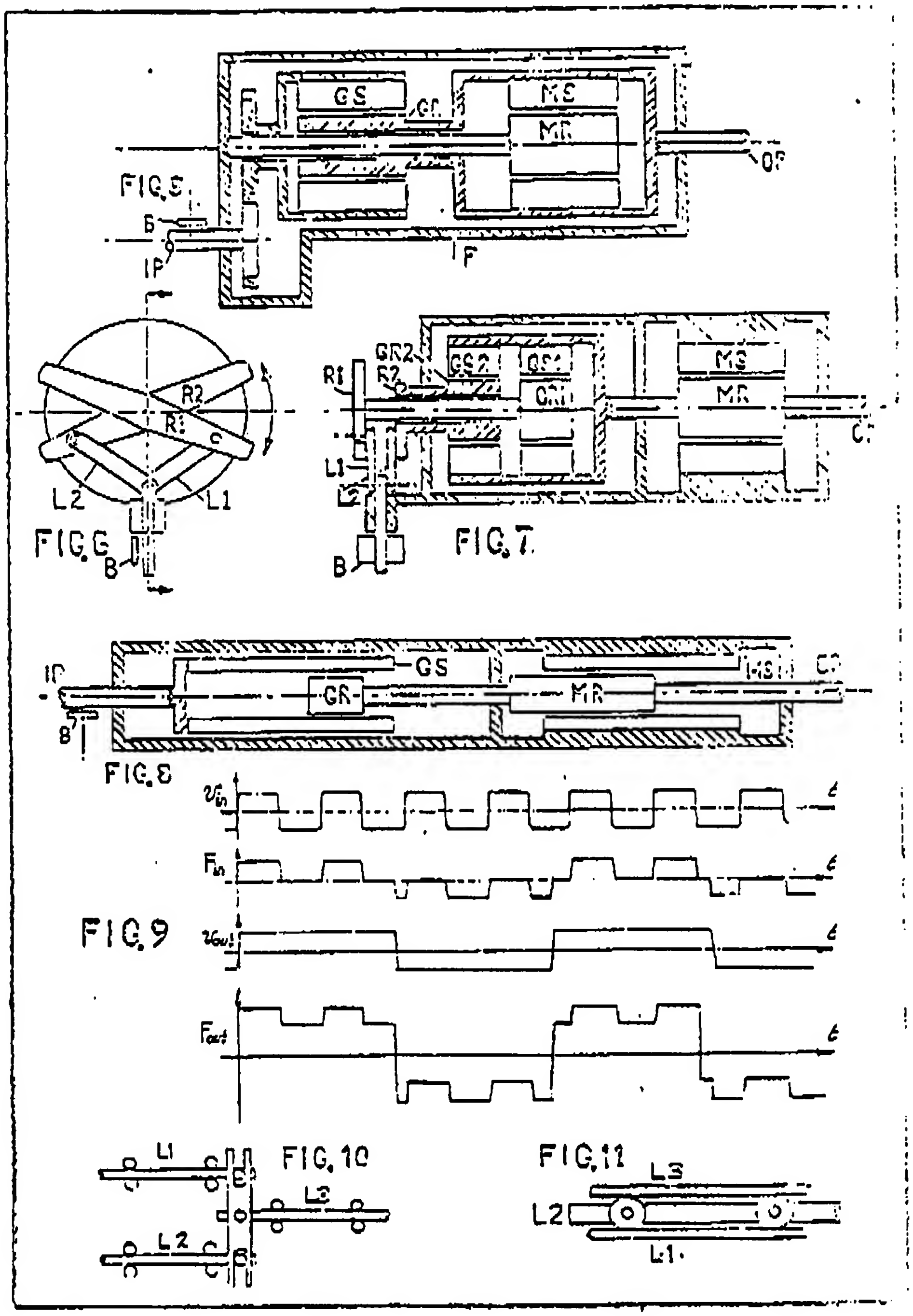

FIG.5
GS
GR
MS
MR
OP
B
IP
F
FIG.6
R2
R1
L2
L1
B
FIG.7
GR2
R1
R2
GS2
GS1
MS
MR
L1
L2
B
FIG.8
IP
GS
GR
MR
MS
B
FIG.9
v_{in}
F_{in}
v_{out}
F_{out}
FIG.10
L1
L2
L3
B
FIG.11
L3
L2
L1

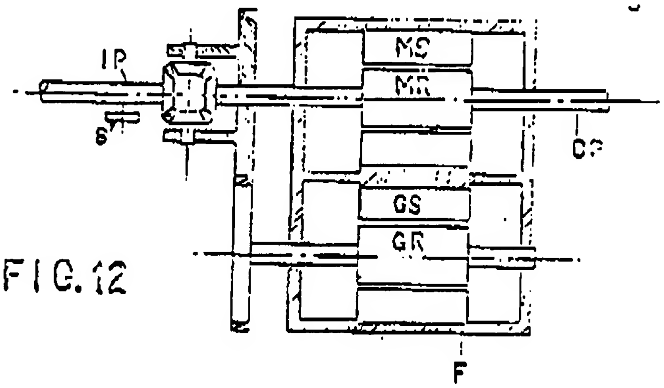

FIG.12

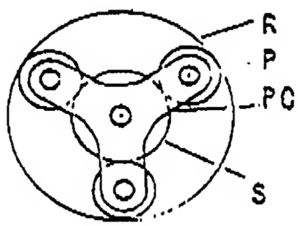

FIG 13

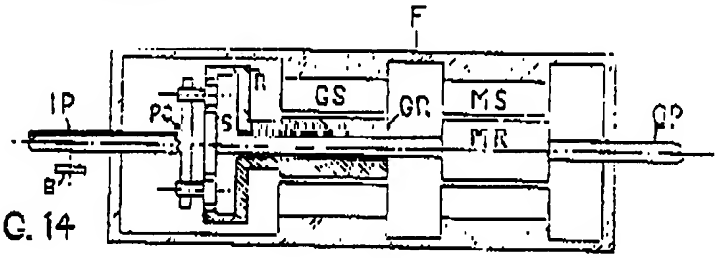

FIG.14

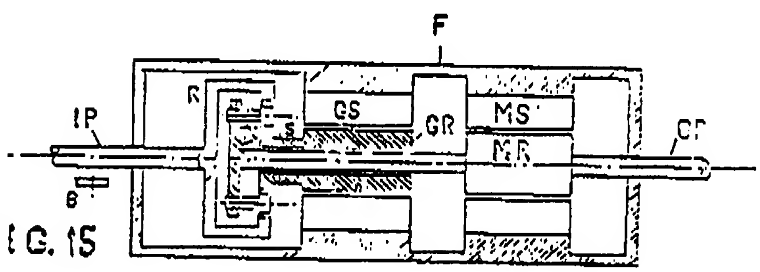

FIG.15

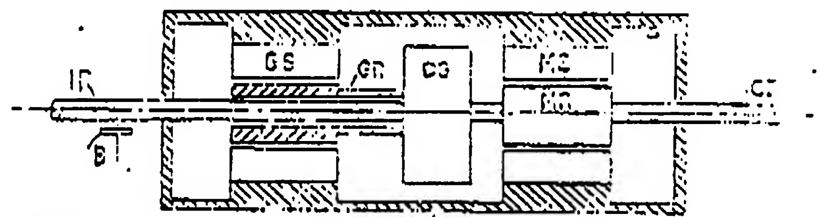

FIG.16

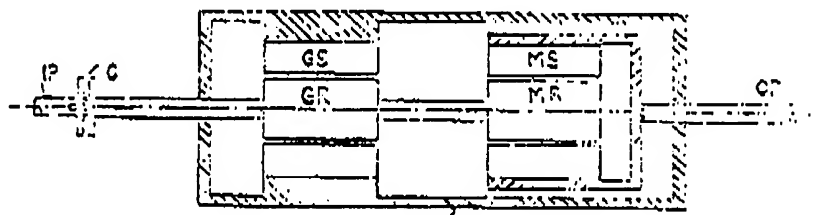

FIG.17

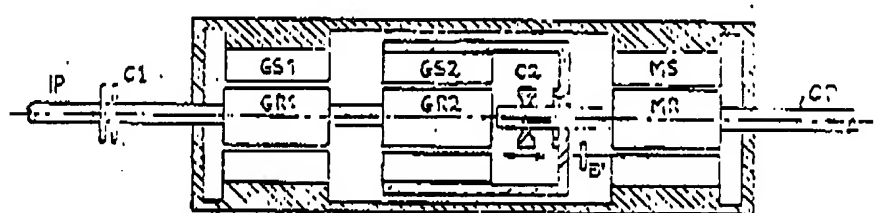

FIG.18

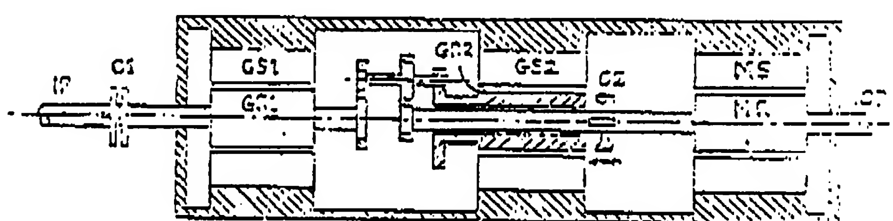

FIG.19

FIG.20

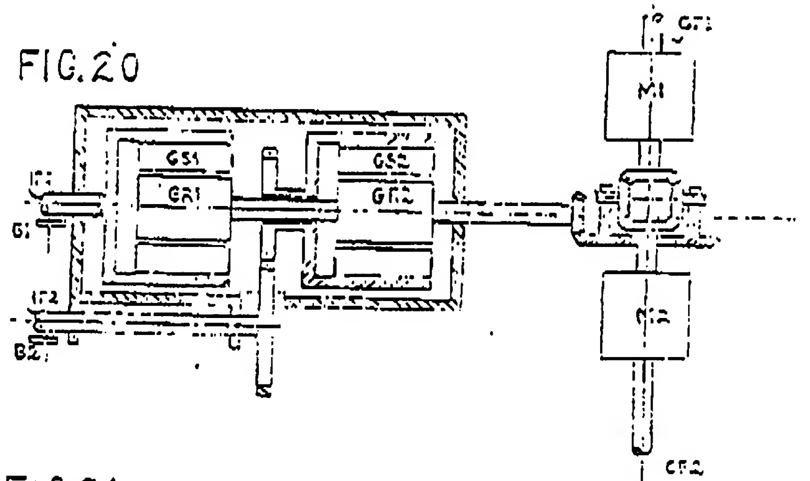

FIG.21

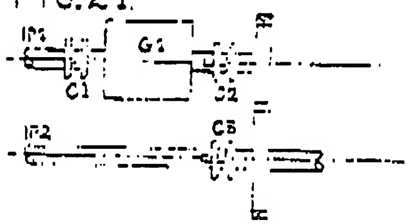

FIG.22

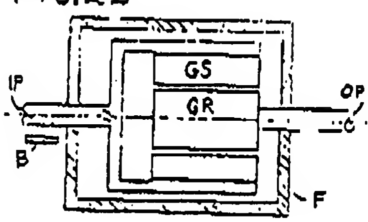

FIG.23

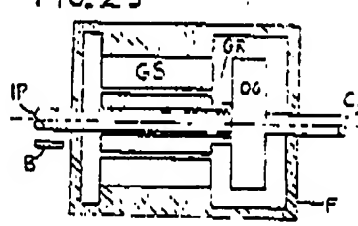

FIG.24

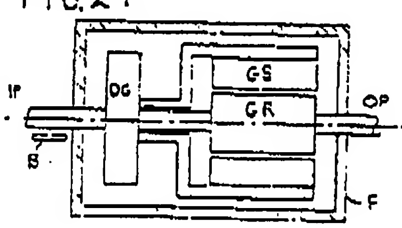

FIG.25